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I, Hajime Inoue, a Patent Attorney, of Ogikubo TM Bldg. 2F, 5-26-13, Ogikubo, Suginami-ku, Tokyo 167-0051, Japan, solemnly and sincerely declare:

that I have a thorough knowledge of Japanese and English languages; and

that the attached pages contain a correct translation into English of the specification of the following Japanese Patent Application:

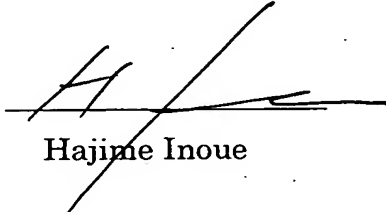
APPLICATION NUMBER

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DATE OF APPLICATION

August 29, 2001

Signed this 10th day of October, 2003.



Hajime Inoue

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[Filing Date]	August 29, 2001
[Attention]	Director-General, The Patent Office
[IPC]	H01M 4/57
[Title of the Invention]	ELECTRODE MATERIAL FOR LITHIUM SECONDARY BATTERY AND LITHIUM SECONDARY BATTERY USING THE SAME
[Number of Claims]	11
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[List of the Documents Attached]

[Document] Specification 1 copy

[Document] Drawings 1 copy

[Document] Abstract 1 copy

[DOCUMENT NAME] Specification

[TITLE OF THE INVENTION] ELECTRODE MATERIAL FOR LITHIUM
SECONDARY BATTERY AND LITHIUM SECONDARY BATTERY USING THE
SAME

5 [CLAIMS]

[Claim 1] An electrode material for a lithium secondary battery, comprising a carbon fiber formed with vapor growth, the carbon fiber comprising a number of bottomless cup-shaped carbon mesh layers stacked together, the edges of the carbon mesh layers being exposed.

10 [Claim 2] The electrode material for a lithium secondary battery as defined in claim 1,

wherein the electrode material is of hollow structure with no bridge.

[Claim 3] The electrode material for a lithium secondary battery as defined in claim 2,

15 wherein the edges of the carbon mesh layers are exposed on the inner surface of the hollow structure.

[Claim 4] The electrode material for a lithium secondary battery as defined in claim 1, 2, or 3,

20 wherein an area of a portion of the edges of the carbon mesh layers exposed on the exterior surface of the carbon fiber is equal to or larger than 2% of an area of the surface of the carbon fiber.

[Claim 5] The electrode material for a lithium secondary battery as defined in claim 1, 2, 3, or 4,

25 wherein several tens and several hundreds of the bottomless cup-shaped carbon mesh layers are stacked.

[Claim 6] The electrode material for a lithium secondary battery as defined in any one of claims 1 to 5,

wherein the surface portion of the carbon fiber on which the edges of the carbon mesh layers are exposed is irregular and has minute irregularity at the level of atomic size.

[Claim 7] The electrode material for a lithium secondary battery as defined in
5 any one of claims 1 to 6,

wherein an electrolyte is introduced and held in the hollow portion of the carbon fiber.

[Claim 8] The electrode material for a lithium secondary battery as defined in
any one of claims 1 to 7, —

10 wherein the carbon fiber is an anode material.

[Claim 9] The electrode material for a lithium secondary battery as defined in
any one of claims 1 to 7,

wherein the carbon fiber is a cathode material.

[Claim 10] A lithium secondary battery in which the anode material as defined
15 in claim 8 is used for an anode.

[Claim 11] A lithium secondary battery in which the cathode material as
defined in claim 9 is used for a cathode.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

20 [TECHNICAL FIELD OF THE INVENTION]

The present invention relates to an electrode material for a lithium secondary battery and a lithium secondary battery using the same.

[0002]

[PRIOR ART]

25 Among various types of secondary batteries, a lithium secondary battery is used as a power supply indispensable for information communications equipment represented by portable telephones and notebook personal computers, and contributes to

reduction of the size and weight of mobile equipment.

Graphite or carbon fibers are used as an electrode material (additive) for such a lithium secondary battery in order to attain various purposes such as increase of the strength, application of the electrical conductivity and the like.

5 Both the cathode and anode materials in the lithium secondary battery are of layered structure. Upon charging, lithium ions are extracted from the cathode and introduced between the carbon mesh layers of the anode to form a lithium intercalation compound. Upon discharging, reversely, a reaction occurs in which lithium ions moves from the carbon anode to the cathode.

10 As described above, the carbon electrode material has a function of occluding and releasing lithium ions. The quality of this occluding and releasing function greatly influences the battery characteristics such as charging and discharging.

[0003]

[PROBLEMS TO BE SOLVED BY THE INVENTION]

15 Graphite and particularly anisotropic graphite has a typical layered structure in which graphite intercalation compounds (GICs) are formed by introducing various types of atoms and molecules. When lithium ions are introduced between the graphite layers, the electrode materials (and particularly the anode material) are expanded due to increase of the gaps between the layers. If the charging and discharging are repeated in
20 such a state, the electrode may be deformed or lithium metal may easily be separated out. This leads to capacity deterioration or internal short-circuiting. Moreover, if the gaps between the layers are repeatedly expanded and contracted, the graphite crystal structure will be broken, whereby the cycle characteristic (lifetime) of the battery may be adversely affected. In addition, there is a problem in that the graphite is inferior to
25 the electrical conductivity as the electrode material.

On the other hand, it is also known that the carbon materials may include a tubular carbon fiber produced with vapor growth. This carbon fiber is of a tubular

configuration which is consisted of a plurality of concentrically arranged carbon mesh layers. When it is to be used as anode material, it raises another problem in that lithium ions can be introduced only into the edge of the fiber, thereby forming lithium intercalation compounds insufficient to provide a satisfactory electric energy density and thus capacity. Moreover, the concentrically arranged carbon mesh layers raise a further problem in that when lithium ions are introduced, the gaps between these layers will forcedly be expanded to create a stress, similarly resulting in breaking of the crystal structure.

Furthermore, there is raised a further problem in that the electrode reinforcing effect is insufficiently provided since the tubular carbon fiber does not have a degree of freedom relating to its shape flexibility, thereby being weaker against stresses such as buckling, tensioning, twisting and the like.

[0004]

The present invention is thus made in view of the above-mentioned problem and its object is to provide an electrode material for a lithium secondary battery which can provide an increased lifetime, electric energy density and capacity and which is superior in electrical conductivity and electrode reinforcement, and a lithium secondary battery using such an electrode material.

[0005]

[MEANS TO SOLVE THE PROBLEMS]

An electrode material for a lithium secondary battery according to the present invention is characterized by that it comprises a carbon fiber formed with vapor growth, the carbon fiber comprising a number of bottomless cup-shaped carbon mesh layers stacked together, the edges of the carbon mesh layers being exposed.

The carbon fiber is also characterized by that it is of a hollow configuration with no bridge.

The carbon fiber is further characterized by that the edges of the carbon mesh

layers are exposed on the inner surface of the hollow structure.

It is preferable that an area of a portion of the edges of the carbon mesh layers exposed on the exterior surface of the carbon fiber is equal to or larger than 2% (more preferably 7%) of an area of the surface of the carbon fiber.

5 The carbon fiber is further characterized by that it comprises several tens to several hundreds of the bottomless cup-shaped carbon mesh layers stacked together.

The carbon fiber of the present invention is further characterized by that the surface portion thereof on which the edges of the carbon mesh layers are exposed is irregular and has minute irregularity at the level of atomic size.

10 The carbon fiber of the present invention is further characterized by that the stacked carbon mesh layers are in a range between several tens of thousands and several hundreds of thousands.

Furthermore, an electrolyte can be introduced into and held in the hollow portion of the carbon fiber.

15 The carbon fiber can be used as a cathode material in the lithium secondary battery (electrode additive) and also as an anode material (main electrode material or additive).

The lithium secondary battery according to the present invention is further characterized by that the electrode material is used in the cathode and/or anode.

20 [0006]

[EMBODIMENTS OF THE INVENTION]

Several preferred embodiments of the present invention will now be described in detail with reference to the attached drawings.

An electrode material will first be described.

25 In this embodiment, as the aforementioned electrode material, a carbon fiber formed with vapor growth (which will be referred to "carbon fiber of herring-bone structure") is used in which a great number (several tens of thousands to several

hundreds of thousands) of bottomless cup-shaped carbon mesh layers are stacked together and in which the edges of the carbon mesh layers are exposed.

Moreover, the carbon fiber is of hollow configuration which does not have internal bridges over its length between several tens nanometers and several tens micrometers.

An example of production method will be explained below.

A reactor used was a known vertical reactor.

Benzene was used for a raw material and fed into a reactor chamber with the flow of hydrogen in a flow rate of 0.31/h under a partial pressure equal to the vapor pressure at about 20 degrees Celsius. A catalyst used was ferrocene which was vaporized at 185 degrees Celsius and fed into the chamber at a density of about 3×10^{-7} mol/s. The reaction temperature was about 1100 degrees Celsius while the reaction time was about 20 minutes. Thus, a carbon fiber of herring-bone structure having its average diameter of about 100nm was obtained. By regulating the flow quantity of the raw material and reaction temperature (depending on the size of the reactor), there can be provided the hollow carbon fiber having no bridge over a range of several tens nanometers to several tens micrometers and which comprises a number of bottomless cup-shaped carbon mesh layers stacked together.

[0007]

FIG. 1 is a copy of a transmission electron microscope photograph of a carbon fiber of herring-bone structure produced according to the aforementioned vapor growth process; FIG. 2 is an enlarged view of FIG. 1; and FIG. 3 is a diagrammatic view of FIG. 2.

As will be apparent from these figures, the carbon fiber has a structure that a number of bottomless cup-shaped carbon mesh layers are stacked together. The exterior surface of the carbon fiber includes an amorphous deposited layer of excess carbon formed thereon. The thickness of the deposited layer is equal to about several

nanometers. Reference numeral 14 denotes a center hole. This center hole has a sufficient space to hold an electrolyte. As will be apparent from FIGs. 1 to 3, the carbon fiber comprises a number of bottomless cup-shaped carbon mesh surfaces 10 stacked together and is of hollow configuration having no bridge over its length between several
5 tens of nanometers and several tens of micrometers.

When the carbon fiber formed with such a deposited layer 12 is heated in the atmosphere for one or several hours at a temperature equal to or higher than 400 degrees Celsius and preferably equal to or higher than 500 degrees Celsius and more preferably between 520 degrees Celsius and 530 degrees Celsius, the deposited layer 12 is
10 oxidized and pyrolyzed. As a result, the deposited layer 12 is removed to partially expose the edges of the carbon mesh layers (or six-membered ring edges).

Alternatively, the deposited layer 12 may be removed to expose the edges of the carbon mesh layers by washing the carbon fiber with supercritical water.

Furthermore, the deposited layer 12 can be removed even by dipping the
15 aforementioned carbon fiber into hydrochloric acid or sulfuric acid and heating it up to about 80 degrees Celsius while stirring using a stirrer.

[0008]

FIG. 4 is a copy of a transmission electron microscope photograph of a carbon fiber of herring-bone structure which has been heat-treated in the atmosphere for one
20 hour at a temperature of about 530 degrees Celsius as described; FIG. 5 is an enlarged view of FIG. 4; FIG. 6 is a further enlarged view of FIG. 5; and FIG. 7 is a diagrammatic view of the same.

It is apparent from FIGs. 5 to 7 that such a heat-treatment partially removes the deposited layer 12 to expose the edges of the carbon mesh layers 10 (or carbon
25 six-membered ring edges). In addition, it is believed that the remaining parts of the deposited layer 12 are also almost pyrolyzed and thus simply in contact with the carbon fiber. If the heat-treatment is further performed for several hours while at the same time

the carbon fiber is washed with supercritical water, 100% of the deposited layer 12 can be removed.

As will be apparent from FIG. 4, furthermore, the carbon fiber comprises a number of stacked carbon mesh surfaces each in the shape of bottomless cup and is of hollow configuration extending at least over a range of between several tens of nanometers and several tens of micrometers.

The inclination of the hexagonal carbon mesh layers relative to the center line is between about 25 degrees and about 35 degrees.

[0009]

As can further be seen from FIGs. 6 and 7, the portions of the outer and inner surfaces on which the edges of the carbon mesh layers 10 are exposed exhibit minute irregularities 16 measurable with units of nm (nanometer) or at the level of atomic size. These irregularities 16 were exposed by removing the deposited layer 12 through the aforementioned heat-treatment, although it was not clearly seen before removal of the deposited layer 12 as shown in FIG. 2.

[0010]

The edge of each of the exposed carbon mesh layer 10 is easy to bond other atoms and thus extremely active. It is conceivable that this is based on the fact that when the deposited layer 12 is being removed through the heat-treatment in the atmosphere, functional oxygen groups such as phenolic hydroxyl group, carboxyl group, quinone type carbonyl group and lactone group increase at the edges of the exposed carbon mesh layers, these functional oxygen groups being hydrophilic and highly compatible with various materials.

The hollow structure and the irregularities 16 highly contribute to the anchor effect.

Actually, it has been found that when an anode was formed by bonding a number of such carbon fibers together through a resin binder, applying the bonded

carbon fibers on a copper foil and then drying such an assembly, a good bonding force to the binder was provided, resulting in prolongation of the lifetime thereof.

[0011]

FIG. 8 shows Raman spectra in a carbon fiber having a herring-bone structure (sample No. 24PS) after it has been heat-treated in the atmosphere for one hour at temperatures of 500 degrees Celsius, 520 degrees Celsius, 530 degrees Celsius and 540 degrees Celsius, respectively.

Although the removal of the deposited layer 12 through the aforementioned heat-treatment has been described in connection with FIGs. 5 to 7, the Raman spectra of FIG. 8 clearly show the fact that this sample is a carbon fiber and also has no graphitized structure, from the presence of D peak (1360cm^{-1}) and G peak (1580cm^{-1}).

[0012]

In other words, it is believed that the aforementioned carbon fiber of herring-bone structure has a turbostratic structure in which the carbon mesh faces are shifted (or ground).

This carbon fiber of turbostratic structure has a stacked structure in which the hexagonal carbon mesh layers are arranged parallel to one another, but such a stacked structure includes hexagonal mesh layers shifted or rotated in the horizontal direction and does not have any crystallographic regularity.

The feature of this turbostratic structure is that the intercalation between the layers is hard to occur. However, atoms in the level of such a size as in lithium ion are permitted to intercalate between the layers.

[0013]

FIG. 9 shows Raman spectra of carbon fibers, samples No. 19PS and No. 24PS, which have the edges of carbon mesh layers exposed through the aforementioned heat-treatment.

FIG. 10 shows Raman spectra of the same carbon fiber samples No.19PS and

No.24PS heat-treated at 3000 degrees Celsius (normal graphitization process) after the edges of the aforementioned carbon mesh layers have been exposed.

It can be seen from FIG. 10 that the D peaks remain even if the graphitization is performed for the carbon fibers in which the edges of the carbon mesh layers are exposed. This means that the carbon fiber is not graphitized by the graphitization.

A diffraction line did not appear at the 112 plane in X-ray diffractometry (not shown). This also shows that the carbon fiber was not graphitized.

[0014]

It is conceivable that the carbon fiber is not graphitized by the graphitization since the deposited layer 12 which can easily be graphitized has been removed. It has also found that the remaining parts of the herring-bone structure are not graphitized.

The carbon fiber thus obtained in which the edges of the carbon mesh layers are exposed can be used as an electrode material for a lithium secondary battery (or electrode additive).

[0015]

The electrode material (carbon fiber) of this embodiment is extensible in the longitudinal direction, since a great number of bottomless cup-shaped carbon mesh surfaces 10 are stacked to provide a hollow structure having no bridge over the length between several tens of nanometers and several tens of micrometers. When the lithium ions enter between the carbon mesh layers 10 through the outer and inner surfaces, the gaps between the carbon mesh layers 10 are expanded to elongate the carbon fiber in the longitudinal direction (FIG. 11). On the contrary, when the lithium ions are released from between the gaps between the carbon mesh layers 10, these gaps are reduced to shorten the carbon fiber in the longitudinal direction (FIG. 12).

This means that in fact, the carbon fiber will not substantially be subjected to physical stress without breaking its crystal structure since any stress created due to the repeated entering and releasing of the lithium ions is absorbed by the expansion and

contraction of the carbon fiber and also since the entering and releasing of the lithium ions are performed through both the outer and inner surfaces of the carbon fiber. This also improves the high power and lifetime properties in the battery with the performance being stabilized.

5 [0016]

In this regard, if the graphite is used as anode material, its crystal structure is easily be broken since graphite is hard to be simply expanded and recovered through the entering and releasing of the lithium ions. If a tubular carbon fiber consisting of concentrically stacked carbon mesh layers is used as anode material, a great stress will
10 be repeatedly exerted to the carbon fiber since the lithium ions penetrate through the edge of the tube forcibly.

[0017]

The electrode material (carbon fiber) in this embodiment is in the form of bottomless cup.

15 The electrode material has such a feature that the edges of the bottomless cup-shaped carbon mesh layers exposed through the inside and outside of the fiber have an extremely high activity. The lithium ions are easily adsorbed on the edges an edge having such the high activity. Thus, the carbon fiber of the present invention can more occlude lithium ions. This leads to increase the battery capacity. In addition, the fact that
20 the electrolyte is also held in the center hole 14 of the carbon fiber assists the occlusion of more lithium ions at the edges exposed within the fiber and leads to increase of the battery capacity.

[0018]

It is preferable that the carbon fiber is used to regulate the length of the carbon
25 fiber having several tens to several hundreds of the bottomless cup-shaped carbon mesh layers.

The length of the carbon fiber may preferably regulate by grinding through ball

milling.

An embodiment of the present invention in which the length of the carbon fiber is regulated by the ball milling will now be described.

A ball mill used was one available from Asahi Rika Seisakujo. Balls used are made of alumina and each has a diameter of 5mm. The aforementioned carbon fibers of 1g, alumina balls of 200g and distilled water of 50cc were placed in a cell and then treated by rotating the cell at a rotational velocity of 350 rpm. Samplings were carried out after 1, 3, 5, 10 and 24 hours, respectively.

[0019]

FIG. 13 shows a distribution of carbon fiber length at each sampling time, measured using a laser particle size distribution meter.

As can be seen from FIG. 13, the linear length will be reduced as the milling time increases. Particularly, the linear length is sharply reduced to be equal to or smaller than 10 micrometers after 10 hours have passed. After 24 hours, another peak occurs at about one micrometer. This clearly means that the fiber length is further reduced. It is conceivable that the appearance of peak at about one micrometer results from the double counting of diameters since the length becomes substantially equal to the diameter.

[0020]

FIG. 14 is a copy of a transmission electron microscope photograph for a very interesting carbon fiber in which the length is regulated to provide several tens of the bottomless cup-shaped carbon mesh layer stacked together. The carbon fiber is hollow with no bridge. Moreover, the edges of the carbon mesh layers are exposed on the outer and inner surfaces of the hollow portion. This carbon fiber has a length and diameter both equal to about 60nm and is in the form of a wall-thinned tube having an increased hollow portion. The carbon fiber may be regulated into any one of various lengths depending on the ball milling conditions.

It has been found that the bottomless cup-shaped carbon mesh layers may be separated and fragmented without breakage.

In this regard, it was difficult to regulate the length of the conventional concentric nanotube since it may be fractured, create axial cracks on the outer surface,
5 be finely split or have a so-called non-core state when the nanotube is ground.

[0021]

As discussed above, the carbon fibers are formed into fine particles by regulating the length thereof. Thus, the carbon fibers may be well dispersed in a binder. This means that the bonding force between the carbon fibers and the binder can be
10 strengthened, thereby prolonging the battery lifetime.

Thus, the edges of the carbon mesh layers will more be exposed so that the lithium ions are more absorbed onto these highly active edges. Therefore, a larger occlusion for lithium ions may be provided. This leads to the fact that the battery capacity can be increased. In addition, the fact that the electrolyte is also held in the
15 center hole 14 of the carbon fiber assists the occlusion of more lithium ions at the edges exposed within the fiber and leads to increase of the battery capacity.

[0022]

The anode is formed by applying and hardening the binder-bonded electrode material onto an electrode foil such as copper foil or the like. The binder used may
20 include various resins such as epoxy resin, Teflon (trade name) resin and the like. The content of the binder may be about 5 wt%. For the anode, the graphite may be used as chief material and contain the aforementioned electrode material as additive.

The cathode is formed by applying and hardening the aforementioned electrode material and lithium containing oxides bonded together by the binder on an electrode
25 foil such as aluminum foil or the like. The lithium containing oxides may include various oxides such as LiCoO_2 , LiMn_2O_4 , LiNiO_2 and the like.

If the aforementioned carbon fiber is used as electrode additive, one or more

wt% of the carbon fiber may be added into the electrode.

[0023]

The electrolyte may be any known liquid or gelled electrolytes such as a liquid electrolyte using propylene carbonate as a solvent and lithium perchlorate as a solute or
5 a gelled polymer created by adding a small quantity of organic polymer into such a liquid electrolyte.

The lithium secondary battery can be formed by attaching leads to the anode and cathode, winding the anode and cathode through an insulation separator of porous membrane, placing such an assembly in a casing and sealing the casing after the
10 electrolyte has been impregnated.

FIG. 15 shows a button-shaped lithium secondary battery.

In this figure, reference numeral 21 denotes an upper lid; 22 cathode; 23 a glass filter; 24 anode (anode materials + PTFE); 25 a packing; 26 a lower lid; and 27 an electrolyte.

15 FIG. 16 shows a polymer type lithium secondary battery.

In this figure, reference numeral 28 designates an electrode film; 29 an anode; 30 a polyelectrolyte; and 32 an electrode film.

[0024]

As discussed above, the electrode material according to this embodiment
20 comprises a carbon fiber formed by stacking a number of bottomless cup-shaped carbon mesh layers 10 to provide a hollow structure having no bridge over the length thereof between several tens of nanometers and several tens of micrometers. Thus, it has an increased flexibility in comparison with a simply tubular carbon fiber. The electrode material of the present invention is stronger against various stresses such as buckling,
25 tensioning, twisting and the like and has a superior electrode reinforcing effect and a superior electrical conductivity.

In particular, the anode formed of the aforementioned electrode material has

superior occlusion and release properties for lithium ions and an increased energy density which can highly increase the battery capacity. Moreover, this carbon fiber has an improved stretchability. Thus, it can expand and contract depending on the entering and releasing of lithium ions to absorb the stresses. Even if the charging and discharging are repeatedly performed, the crystal structure of the carbon fiber will not be broken, resulting in improvement of the battery lifetime.

[0025]

[ADVANTAGES OF THE INVENTION]

As described, the present invention can provide an electrode material for a lithium secondary battery which can provide a high power, an increased lifetime, a stabilized performance and an increased battery capacity and which is superior in electrical conductivity and electrode reinforcement, and a lithium secondary battery using such an electrode material.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[FIG. 1]

FIG. 1 is a copy of a transmission electron microscope photograph of a carbon fiber of herring-bone structure produced according to the aforementioned vapor growth process.

[FIG. 2]

FIG. 2 is an enlarged view of FIG. 1.

[FIG. 3]

FIG. 3 is a diagrammatic view of FIG. 2.

[FIG. 4]

FIG. 4 is a copy of a transmission electron microscope photograph of a carbon fiber of herring-bone structure which has been heat-treated in the atmosphere for one hour at a temperature of about 530 degrees Celsius.

[FIG. 5]

FIG. 5 is an enlarged view of FIG. 4.

[FIG. 6]

FIG. 6 is a further enlarged view of FIG. 5.

[FIG. 7]

5 FIG. 7 is a diagrammatic view of FIG. 6.

[FIG. 8]

FIG. 8 shows Raman spectra in a carbon fiber having a herring-bone structure (sample No. 24PS) after it has been heat-treated in the atmosphere for one hour at temperatures of 500 degrees Celsius, 520 degrees Celsius, 530 degrees Celsius and 540
10 degrees Celsius, respectively.

[FIG. 9]

FIG. 9 shows Raman spectra of carbon fibers, samples No. 19PS and No. 24PS, which caused the edges of carbon mesh layers exposed through the aforementioned heat-treatment.

15 [FIG. 10]

FIG. 10 shows Raman spectra of the same carbon fiber samples No. 19PS and No. 24PS heat-treated at 3000 degrees Celsius (normal graphitization process) after the edges of the aforementioned carbon mesh layers have been exposed.

[FIG. 11]

20 FIG. 11 illustrates lithium ions entered between the carbon mesh layers.

[FIG. 12]

FIG. 12 illustrates lithium ions released from between the carbon mesh layers.

[FIG. 13]

FIG. 13 is a graph showing distributions of carbon fiber lengths for various
25 passages of time when the carbon fibers are ground with ball milling.

[FIG. 14]

FIG. 14 is a copy of a transmission electron microscope photograph showing

two carbon fibers separated from each other, each carbon fiber comprising several tens of bottomless cup-shaped carbon mesh layers stacked together.

[FIG. 15]

FIG. 15 shows a button-shaped lithium secondary battery.

5

[FIG. 16]

FIG. 16 shows a polymer type lithium secondary battery.

[EXPLANATION OF REFERENCE NUMERALS]

10	CARBON MESH LAYERS
12	DEPOSITED LAYER
10 14	CENTER HOLE
16	IRREGULARITIES
21	UPPER LID
22	CATHODE
23	GLASS FILTERS
15 24	ANODE
25	PACKING
26	LOWER LID
27	ELECTROLYTE
28	ELECTRODE FILM
20 29	ANODE
30	POLYELECTROLYTE
32	ELECTRODE FILM

FIG. 1

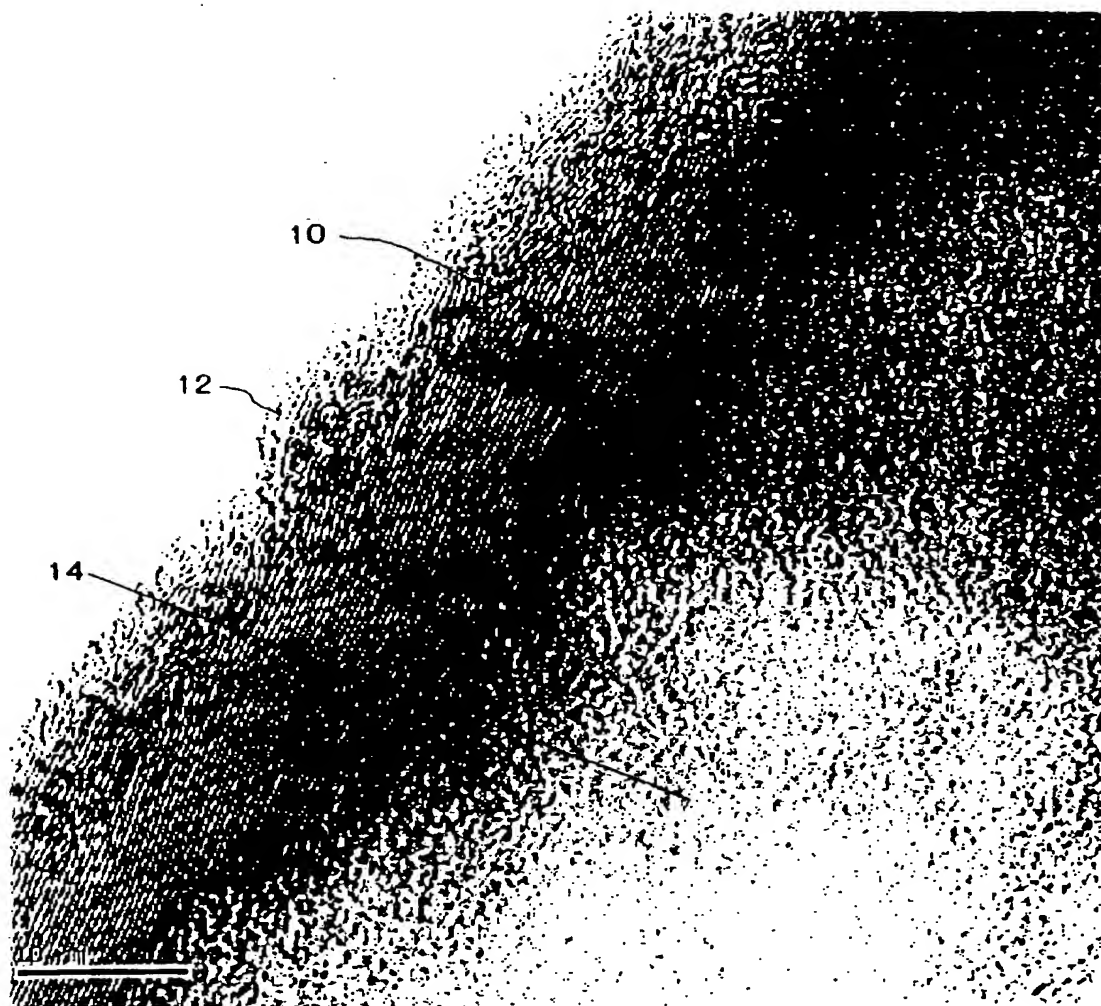


FIG. 2

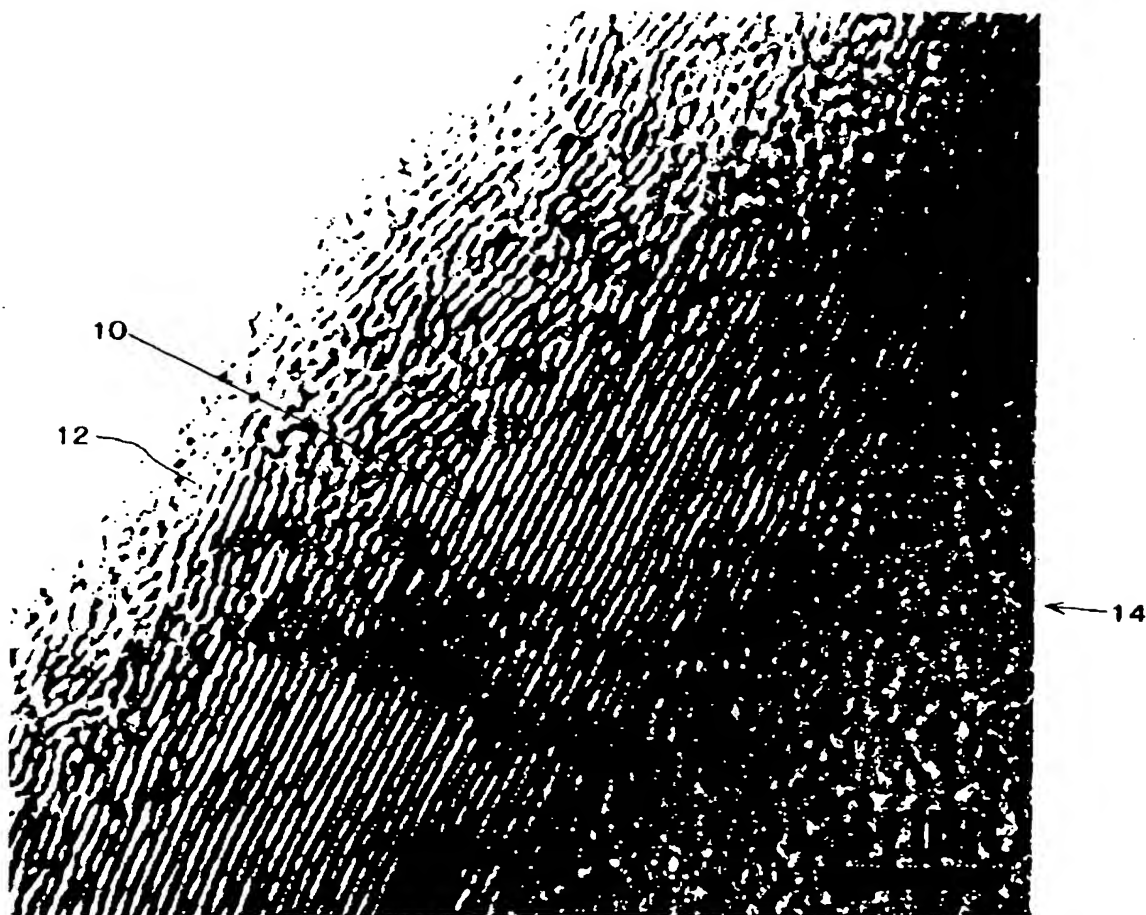


FIG. 3

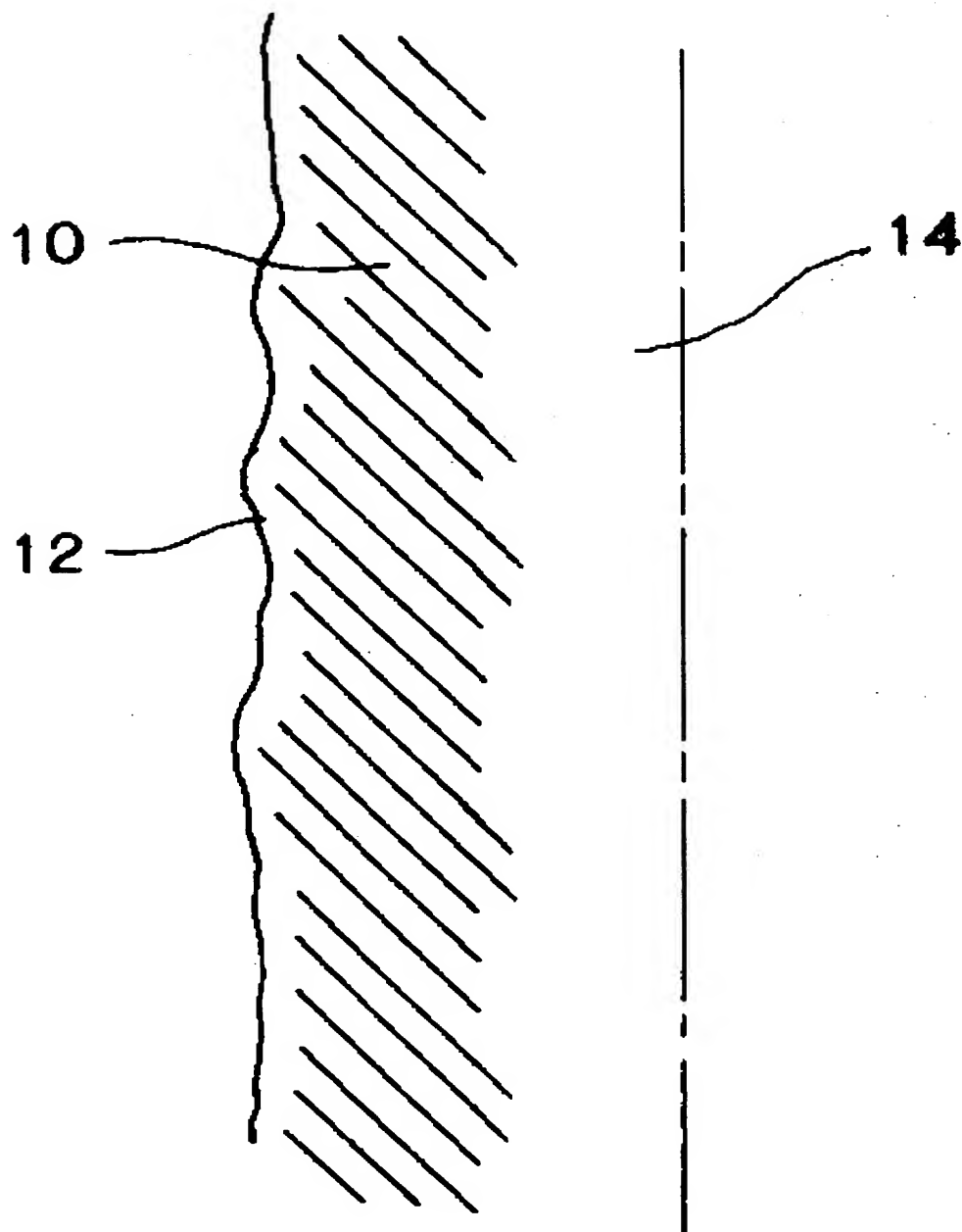


FIG. 4

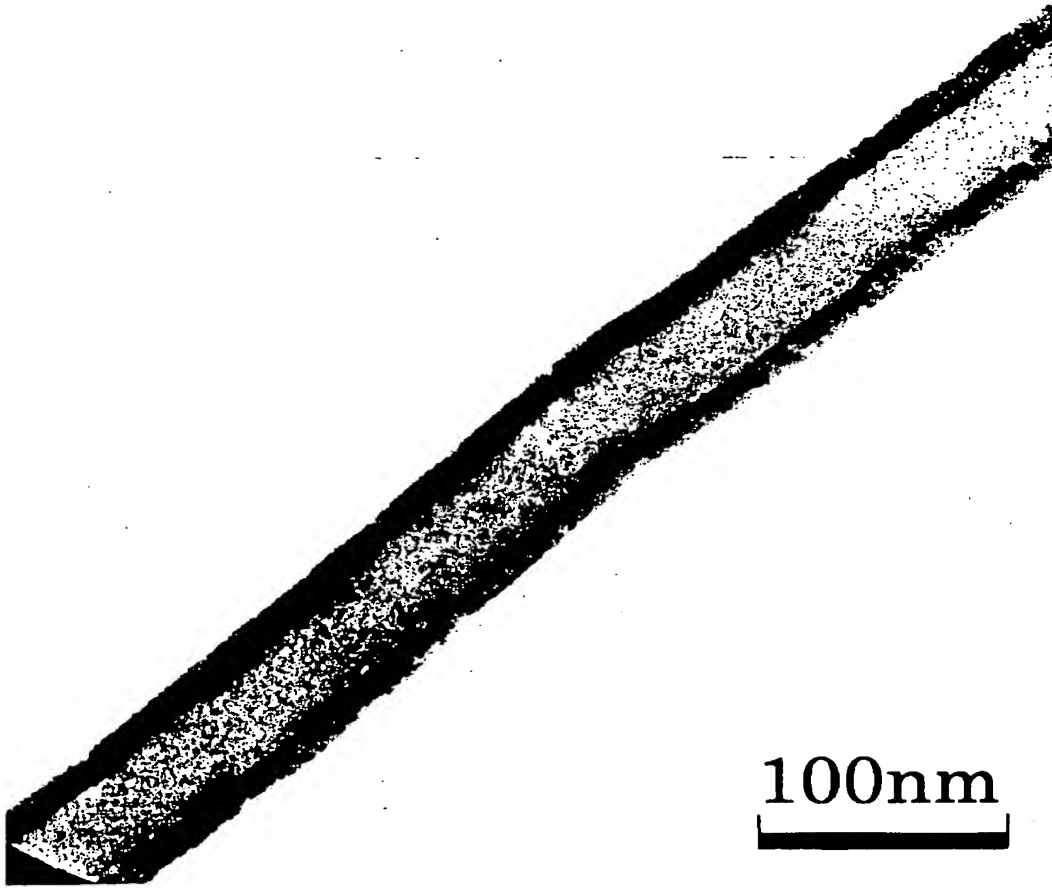


FIG. 5

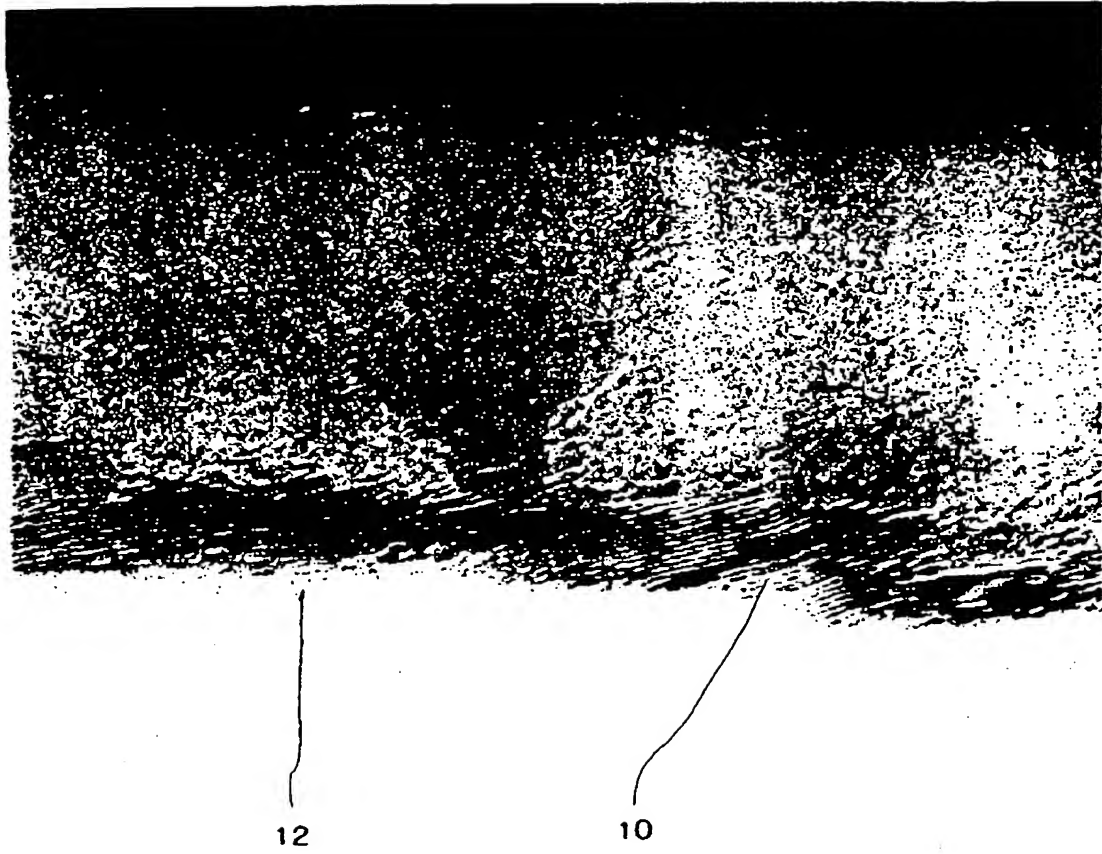
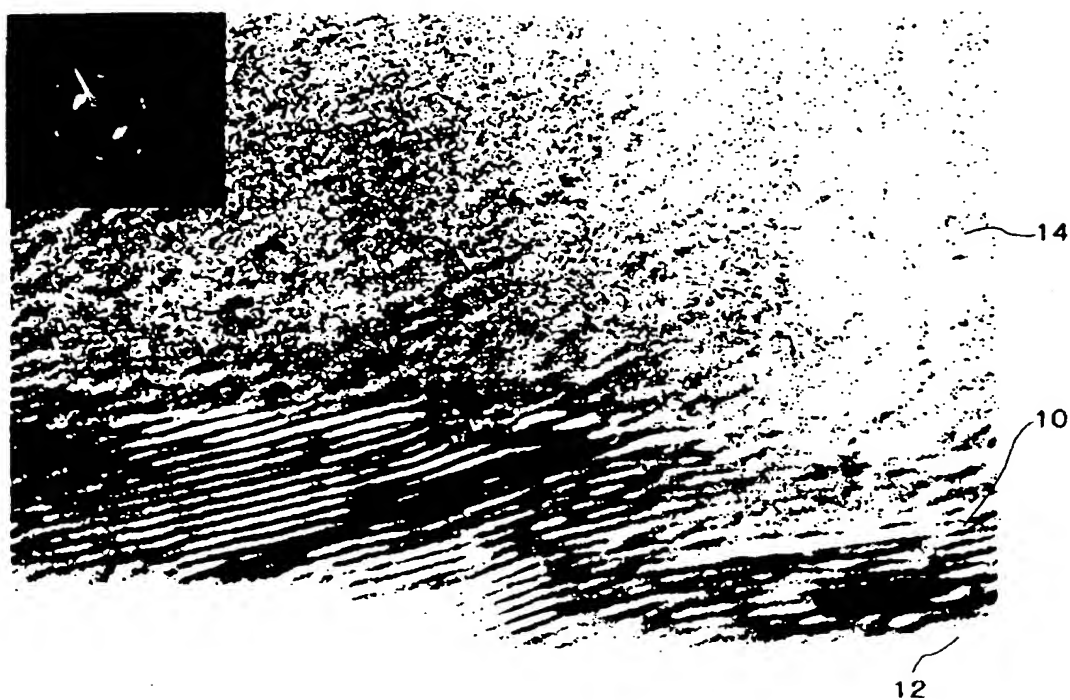


FIG. 6



3nm

FIG. 7

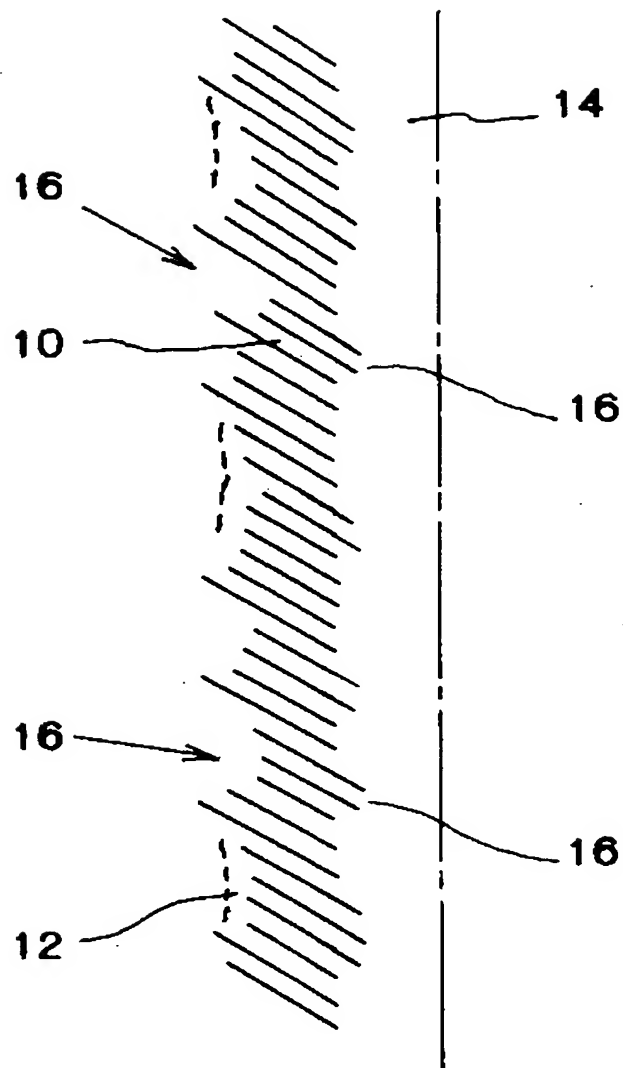


FIG. 8

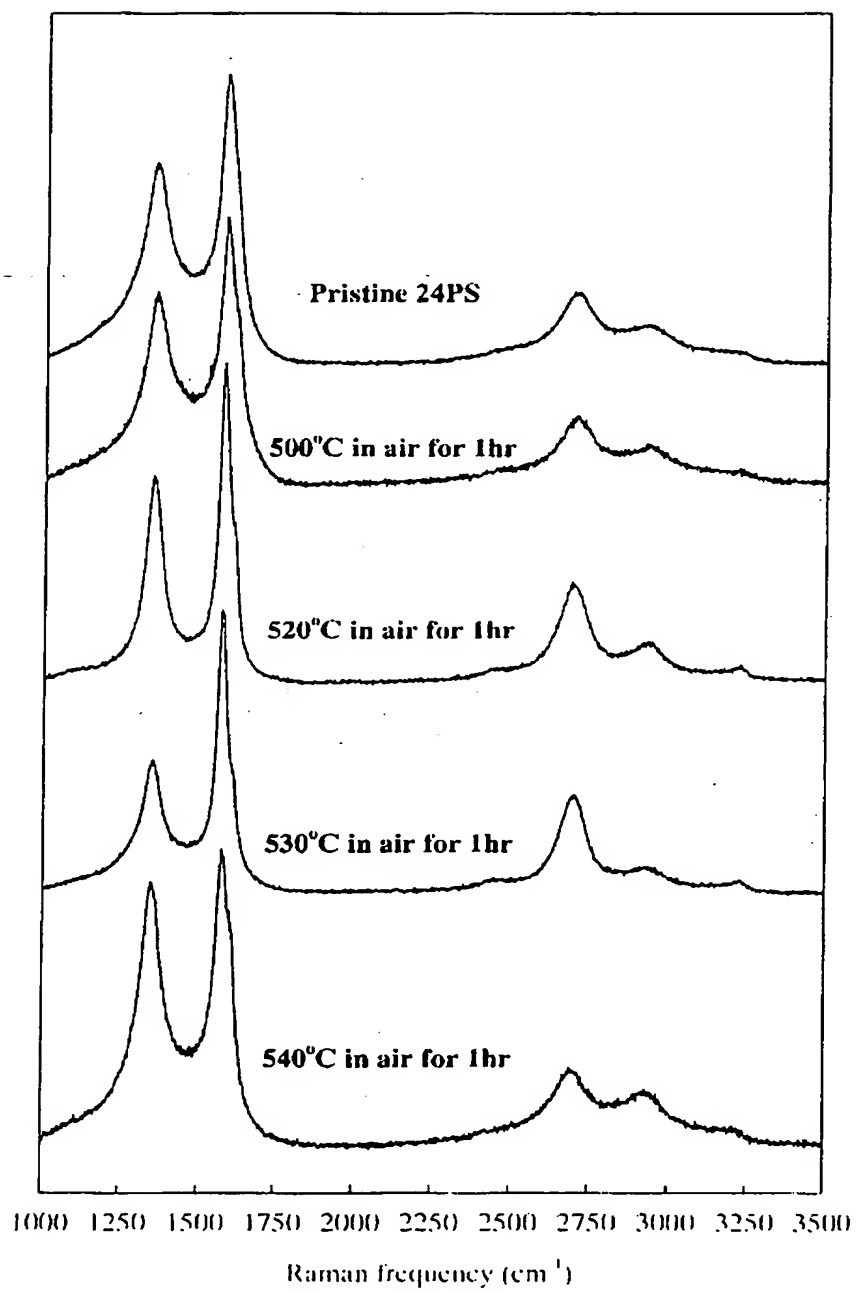


FIG. 9

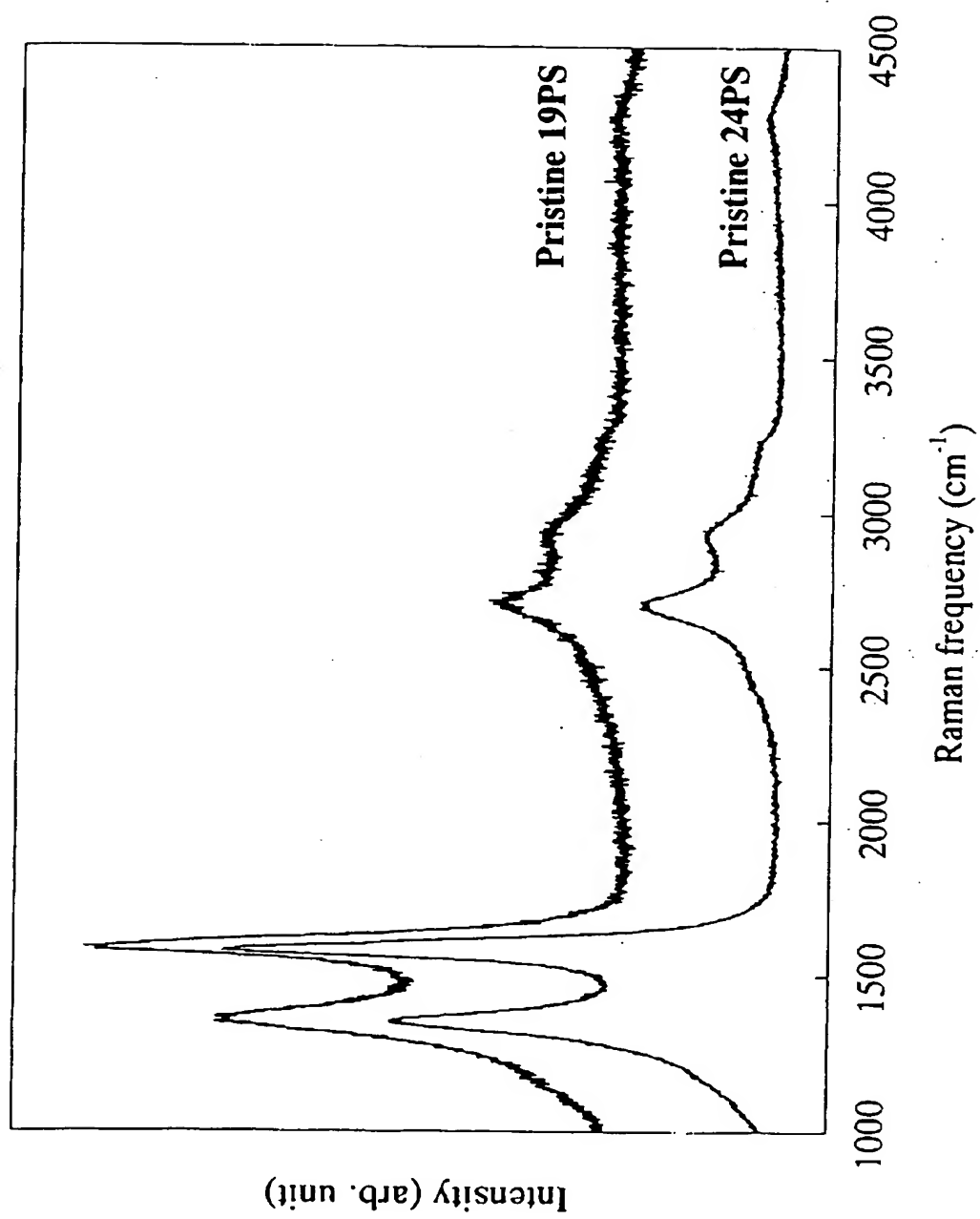


FIG. 10

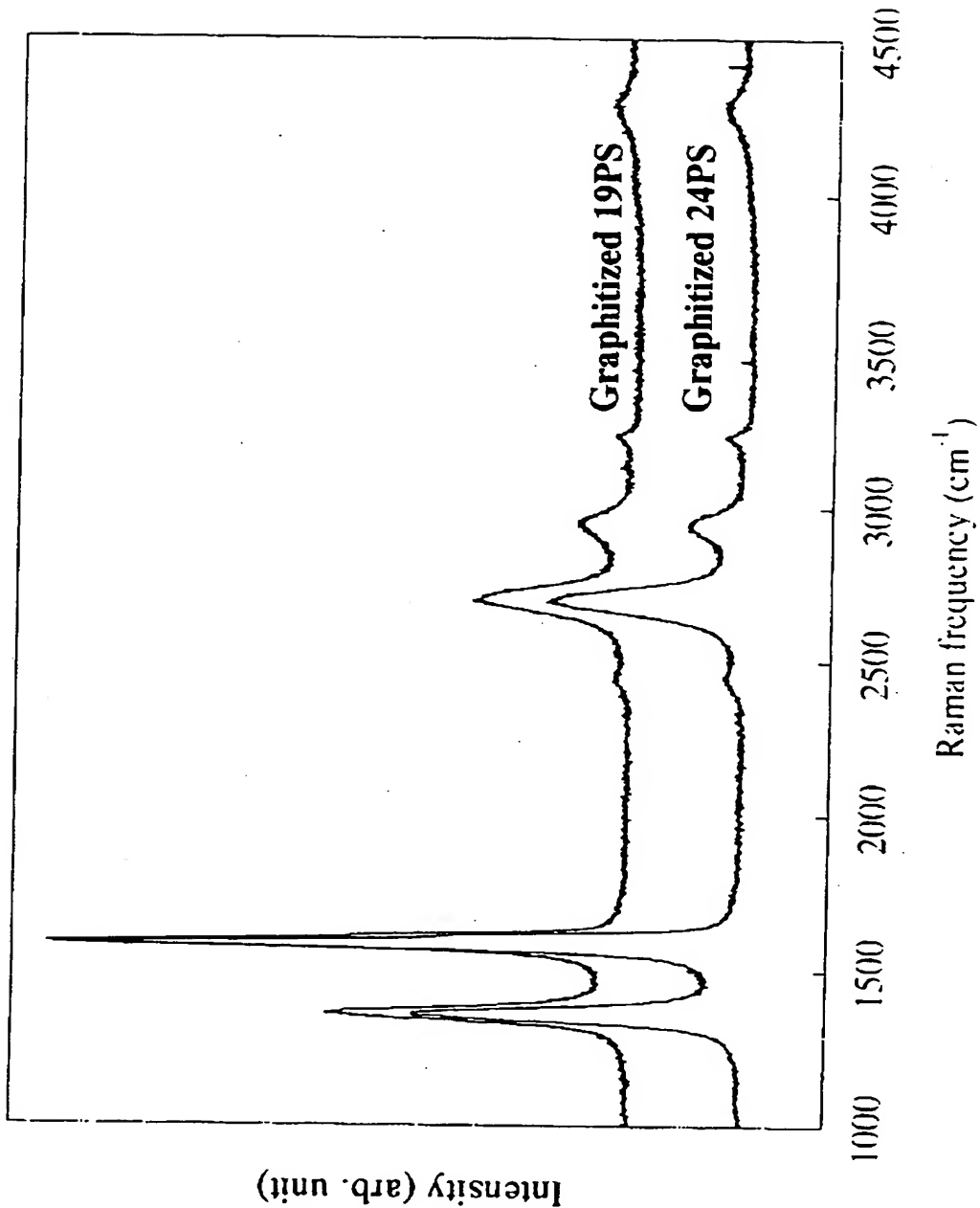


FIG. 11

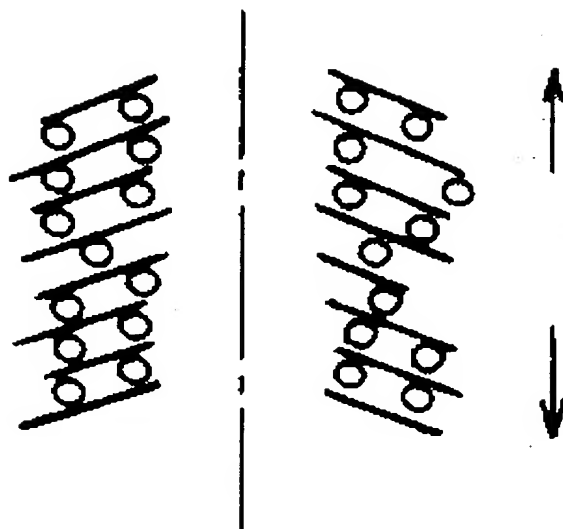


FIG. 12

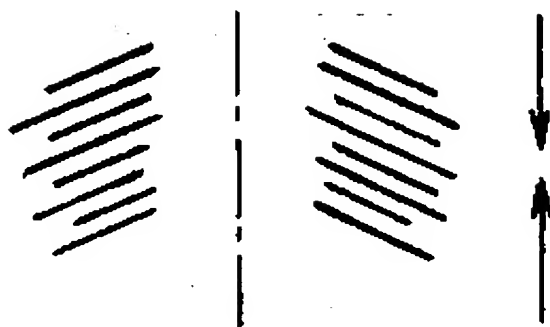


FIG. 13

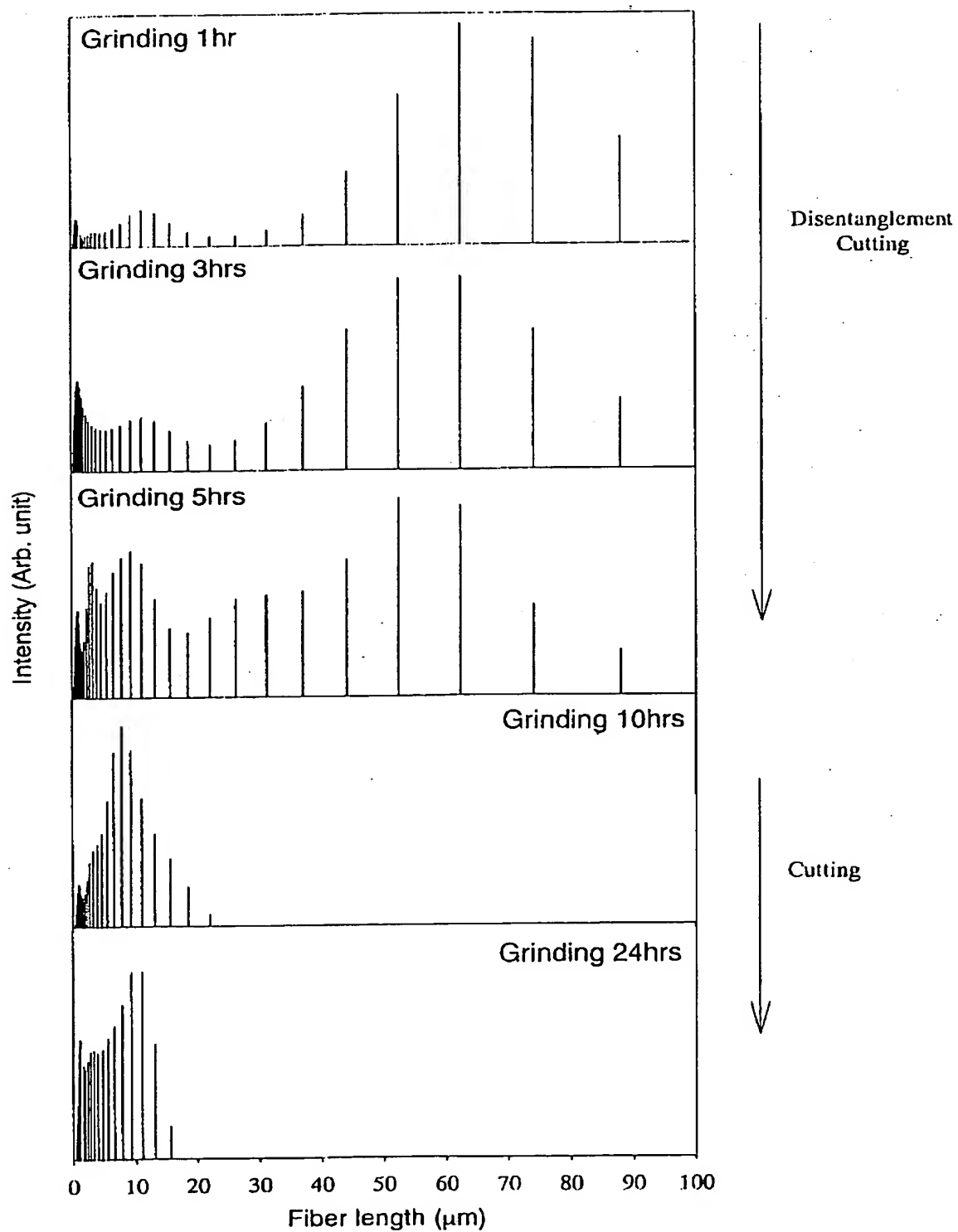


FIG. 14

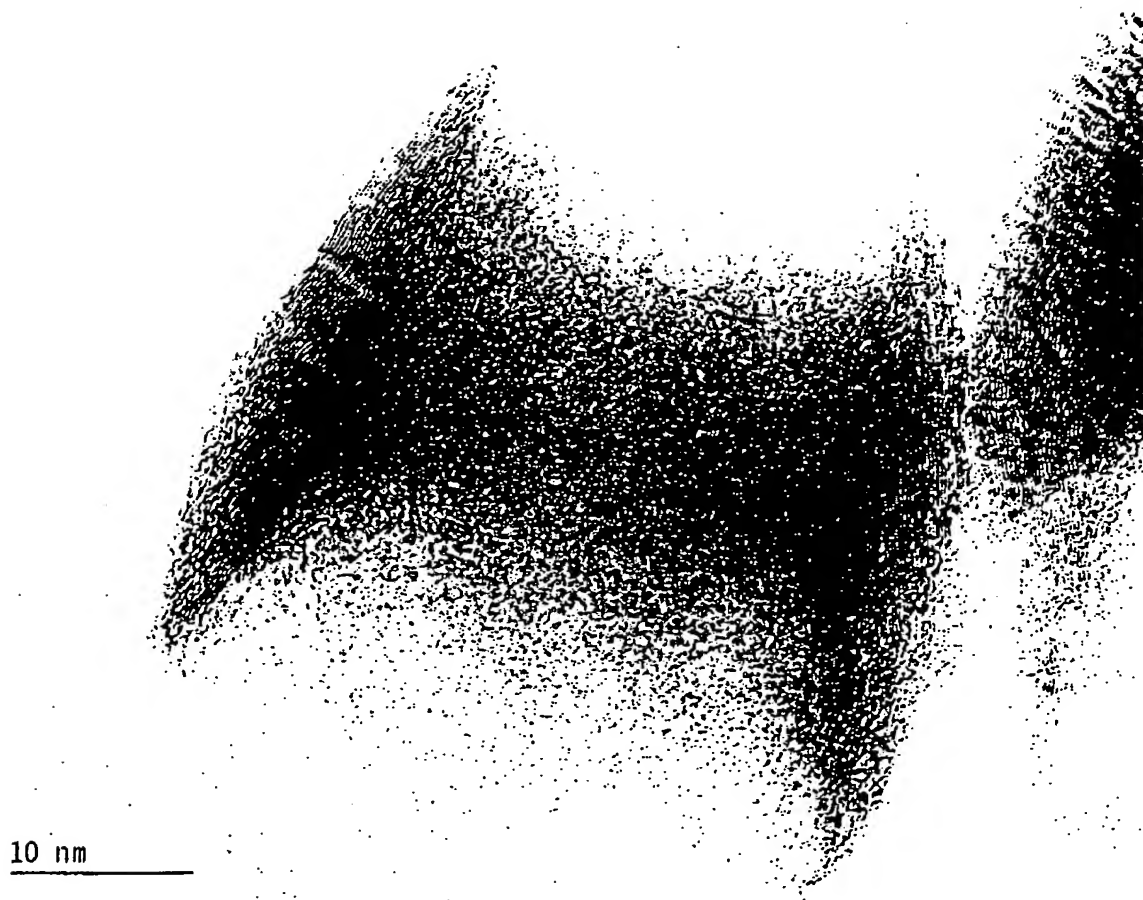


FIG. 15

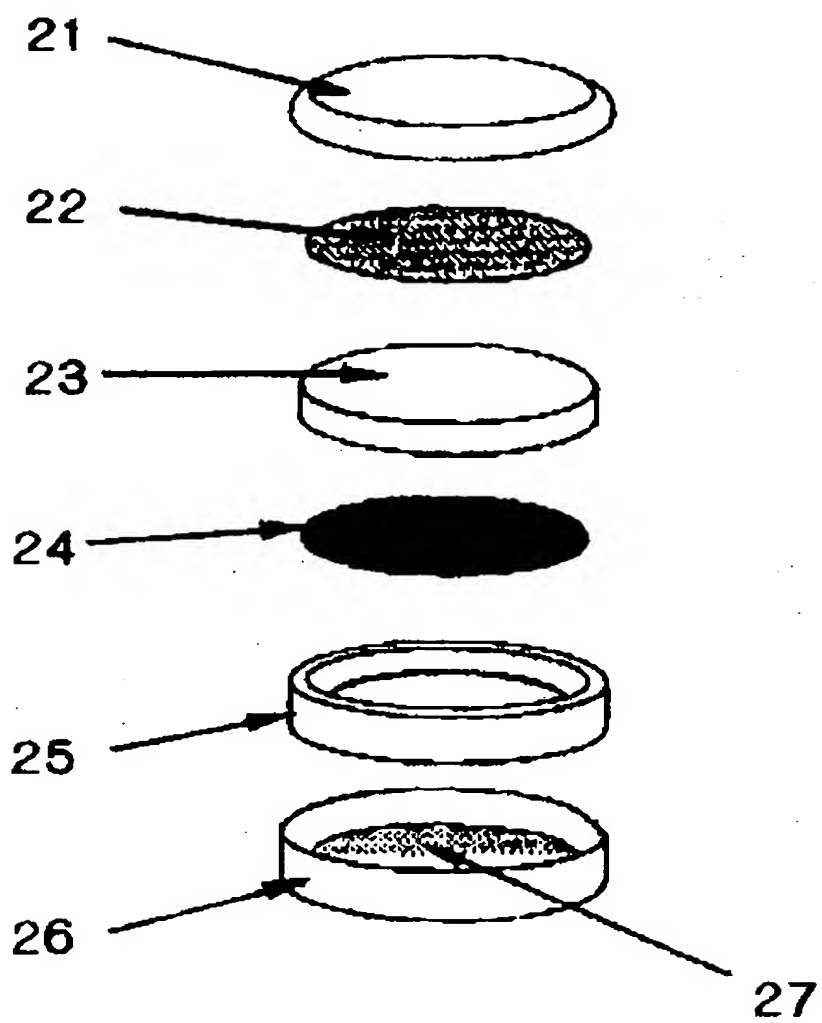
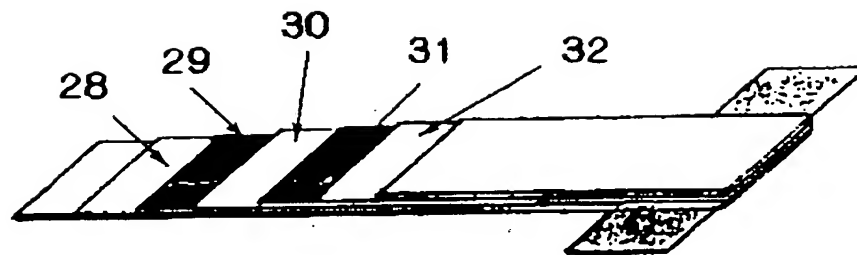


FIG. 16



[DOCUMENT NAME] Abstract

[ABSTRACT]

[Object] To provide an electrode material which can provide an improved battery lifetime, an increased energy density for increasing the battery capacity and
5 which is superior in electrical conductivity and electrode reinforcement.

[Arrangement] An electrode material for a lithium secondary battery according to the present invention is characterized by that it comprises a carbon fiber formed with vapor growth, the carbon fiber comprising a number of bottomless cup-shaped carbon mesh layers stacked together, the edges of the carbon mesh layers being exposed.

10 [Selected Figure] FIG. 2